BEST AVAILABLE COPY

(12) UK Patent Application (19) GB (11) 2 269 024 (13) A

(43) Date of A Publication 26.01.1994

(21) Application No 9315214.8

(22) Date of Filing 22.07.1993

(30) Priority Data
(31) 9215595 (32) 22.07.1992 (33) GB

(71) Applicant(s)
The University Of Nottingham

(Incorporated in the United Kingdom)

University Park, Nottingham, NG7 2RD,
United Kingdom

(72) Inventor(s)
John Richard Fletcher

(74) Agent and/or Address for Service
Swindell & Pearson
48 Friar Gate, DERBY, DE1 1GY, United Kingdom

(51) INT CL^5
G02B 17/08

(52) UK CL (Edition M)
G2J JB7C11

(56) Documents Cited
GB 0812968 A EP 0266005 A2

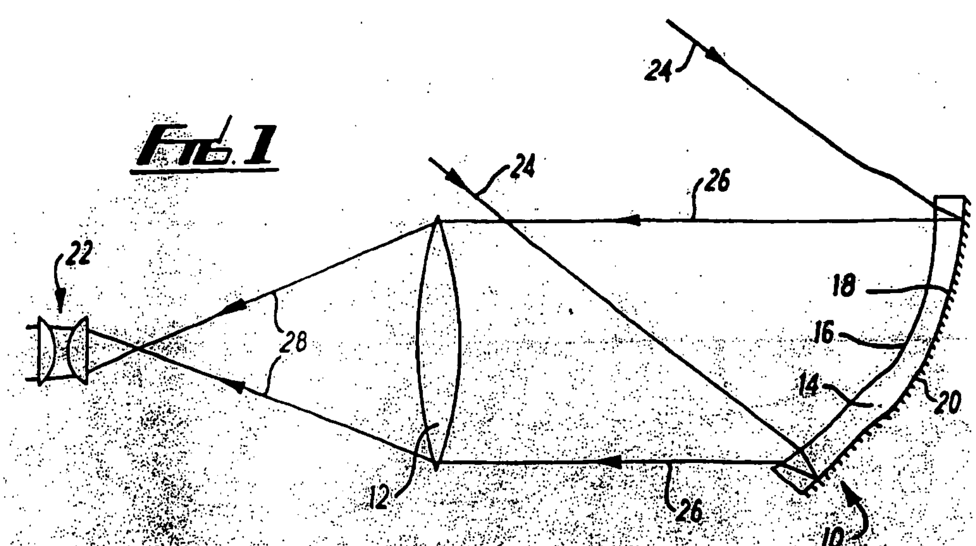
(58) Field of Search
UK CL (Edition L) G2J JB7C11
INT CL^5 G02B

(54) **Optical system having at least one tilted Mangin mirror**

(57) Optical systems incorporating one or more tilted Mangin mirror 10 components comprise a converging lens arrangement 12 to receive the emergent beam from the mirror component to form an image. Aberrations from the mirror may be corrected by selection of a converging arrangement having aberrations of opposite sign. An eyepiece 22 is shown.

The systems may be employed in telescopes as shown, photographic lens arrangements and copying systems.

FIG. 1



GB 2 269 024 A

FIG. 1

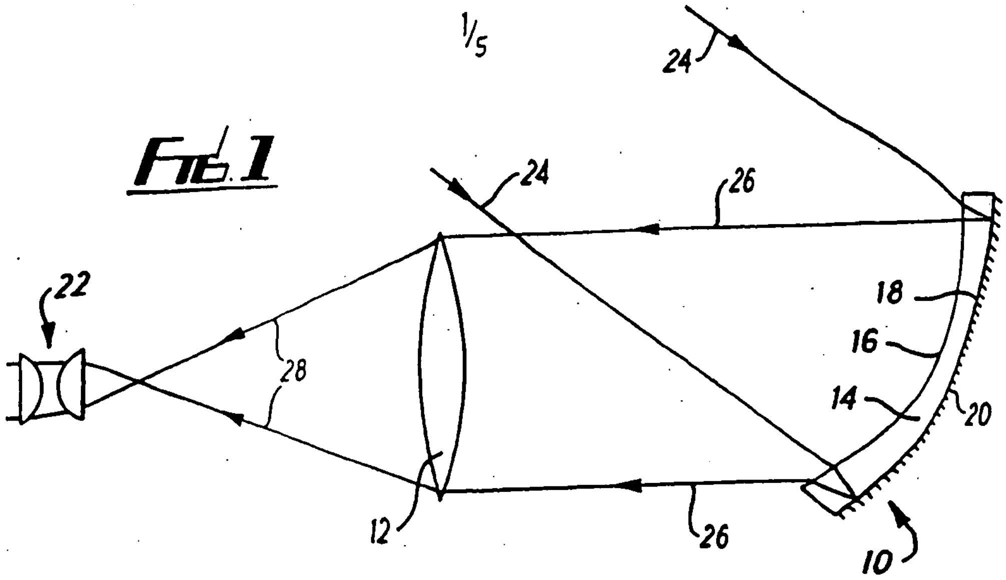
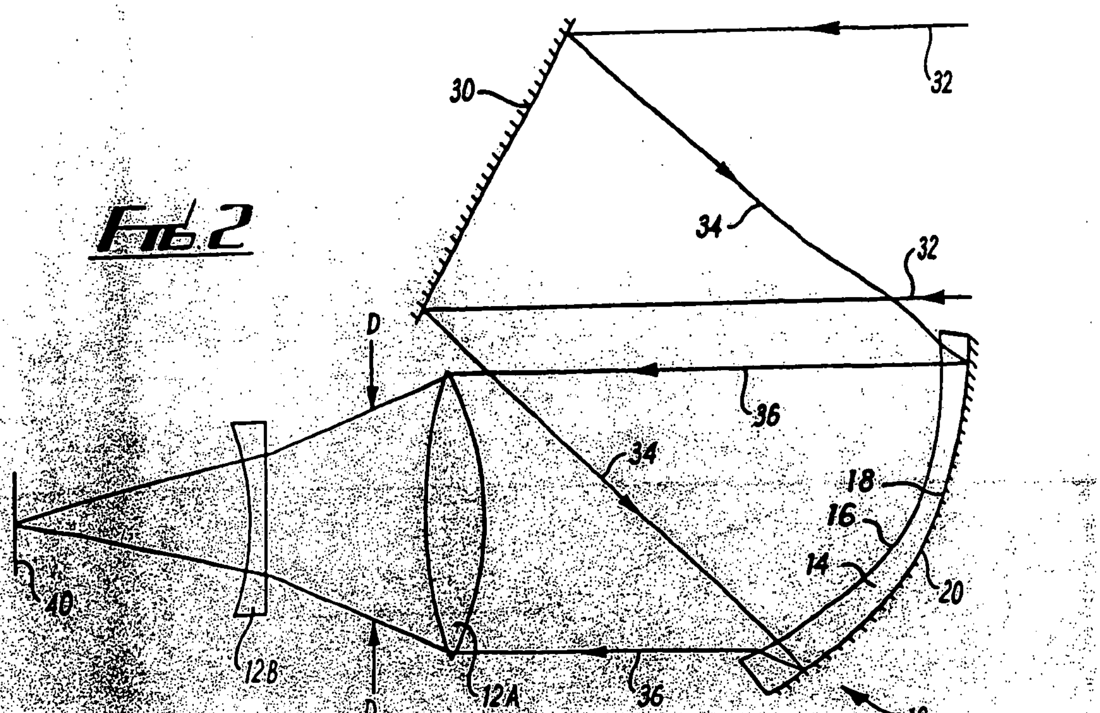

24
24
26
22
18
16
28
14
20
12
26
10

FIG. 2


30
32
34
32
D
36
34
18
16
14
20
40
12B
12A
36
D
10

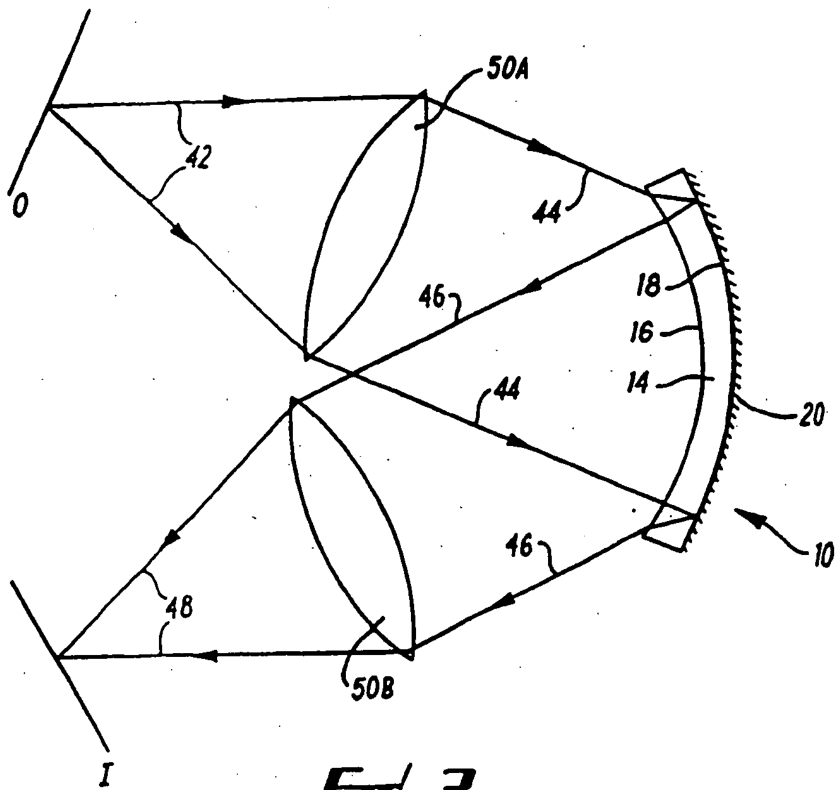


FIG. 3

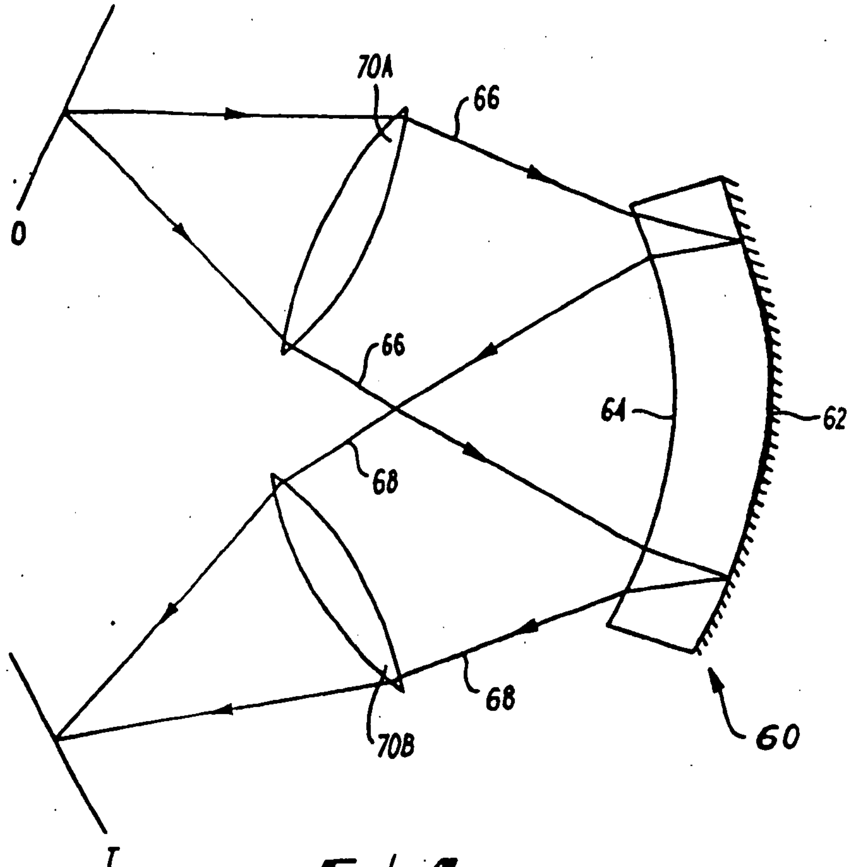


FIG. 4

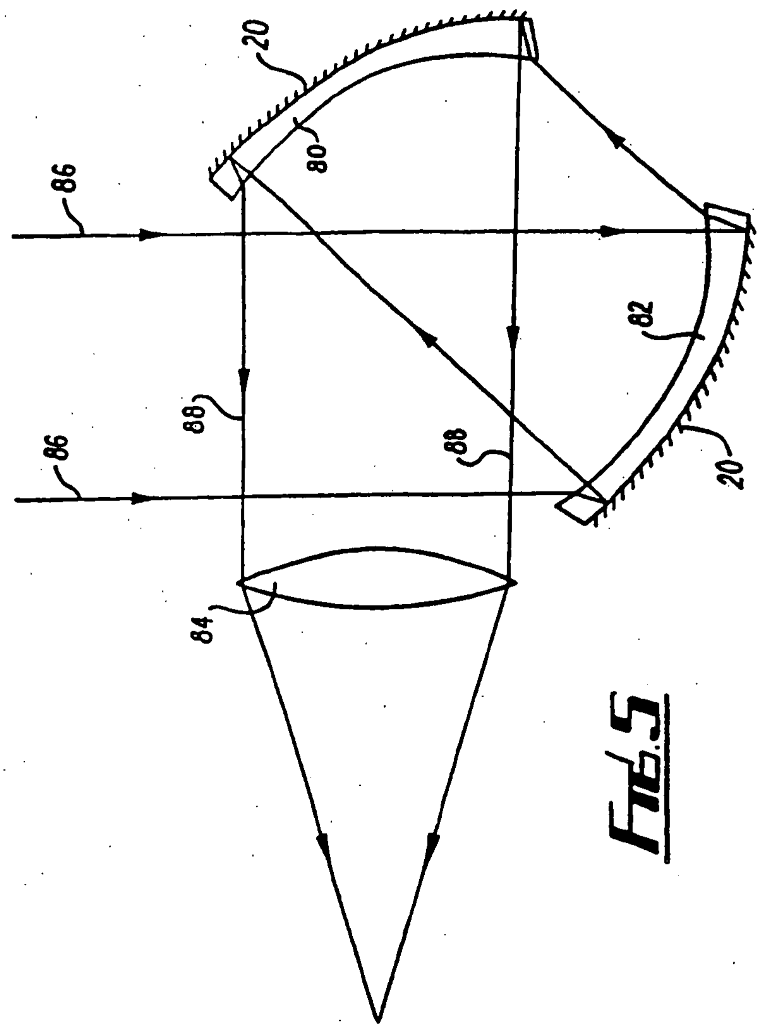


FIG.5

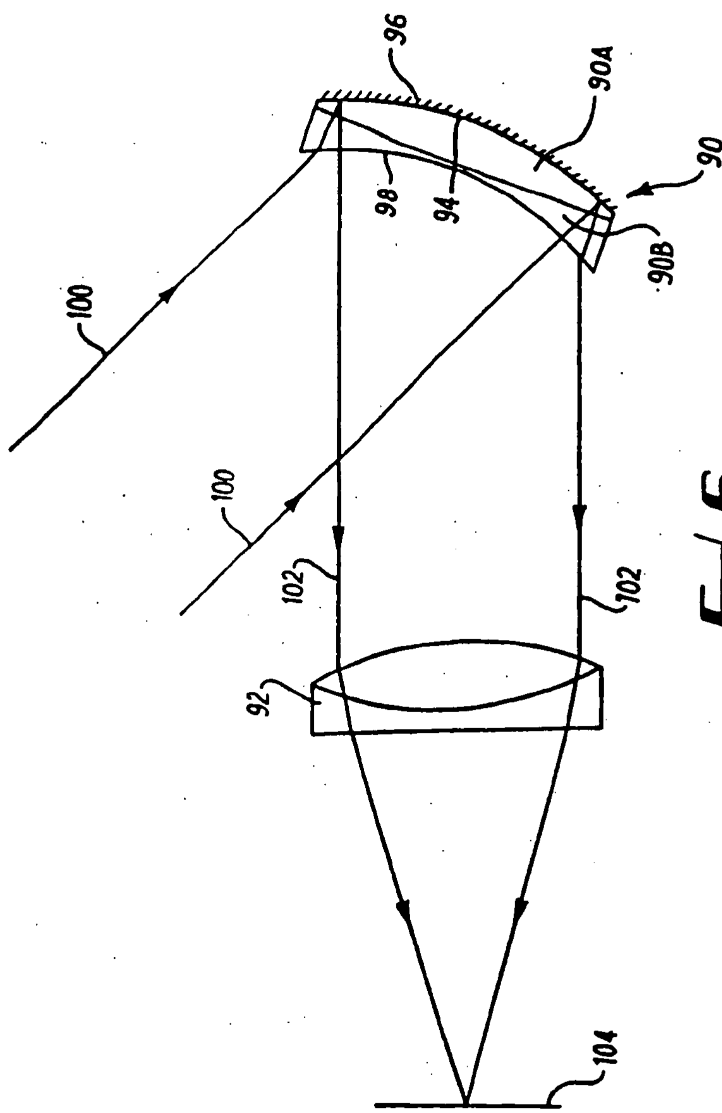


FIG. 6

2269024

Optical Systems

The present invention concerns optical systems, and relates in particular to lens systems incorporating a tilted component.

Long focus lenses of the type used in photography and television may be conveniently divided into two main types, refracting and catadioptric (refracting/ reflecting). Refracting systems suffer from a residual chromatic aberration known as secondary spectrum due to the fact that a lens of a single material will bring light of different wavelengths (colours) into focus at different points (that is, there is a change in refractive index with wavelength). This causes a loss in image quality. The problem can be minimised by using a lens combining two different optical materials. However, this does not provide a complete solution to the problem, even with the best available materials. Moreover, one such material, calcium fluoride, is particularly expensive and fragile and thus far from ideal in practical terms.

Catadioptric systems employ combinations of lenses and mirror components. In the usual photographic systems a significant drawback is that a secondary mirror must be located in the optical path. This causes a loss of image contrast and, more significantly, prevents the use of the

usual iris diaphragm. In addition, as the lens aperture is annular, any out of focus areas of the image appear as rings. The use of mirrors in these lenses also introduces problems caused by scattered light, which cannot always be prevented from reaching the photographic film.

In this specification, the term "Mangin mirror" is to be understood as an optical component consisting of a lens having a convex face and a concave face, and a mirror surface on one side, such that light passes through the lens to the mirror, and is reflected back through the lens. The term "thin" when applied to a Mangin mirror is intended to denote a component the thickness of which at the axis is at least an order of magnitude less than either radius of curvature. A Mangin mirror for which the thickness at the axis is comparable to the radii of curvature is described herein as a thick Mangin mirror.

According to the invention there is provided an optical system comprising at least one tilted thin Mangin mirror component having zero total power, the or each mirror component being arranged to receive an incident light beam from an object and thereby produce an emergent light beam, the incident and emergent beams being symmetrical with respect to the axis of the mirror component, and a converging lens arrangement, the lens arrangement

receiving the emergent beam from the mirror component or components to form an image.

The or each Mangin mirror component may comprise either a single element or two elements cemented together. Each element may be of a different optical material. The materials may be chosen to render the Mangin mirror achromatic.

One preferred system includes a single Mangin mirror having its mirror surface on the convex side thereof.

Preferably the incident beam is a parallel beam, as is the emergent beam.

The system may further include an eyepiece.

The converging lens arrangement may comprise one or more lens elements.

The Mangin mirror component and the converging lens arrangement may be of the same or of different optical materials. Where there is more than one lens element in the converging arrangement, these may be of the same or of different optical materials.

The system may include a diaphragm. The diaphragm may be an iris diaphragm.

The system may include a plane mirror.

According to the invention there is further provided an optical system comprising at least one tilted thick Mangin mirror component having non-zero total power, the or each mirror component being arranged to receive an incident light beam from an object and thereby produce an emergent light beam to form an image, the incident and emergent light beams being symmetrical with respect to the axis of the mirror component, and a converging lens arrangement, the lens arrangement receiving the emergent beam from the mirror component or components to form an image.

The or each Mangin mirror component may comprise either a single element or two elements cemented together. Each element may be of a different optical material. The materials may be chosen to render the Mangin mirror achromatic.

One preferred system includes a single Mangin mirror having its mirror surface on the convex side thereof.

The invention will now be further described for the

purposes of illustration only with reference to the accompanying drawings in which:-

Fig. 1 is a simplified diagrammatic representation of a lens system of the invention for use in a telescope;

Fig. 2 is a simplified diagrammatic representation of a system of the invention for use in a long-focus photographic lens;

Fig. 3 is a simplified diagrammatic representation of a system of the invention for use in a copying system;

Fig. 4 is a simplified diagrammatic representation of an alternative copying system;

Fig. 5 is a simplified diagrammatic representation of a system similar to Fig. 1 but employing two tilted components; and

Fig. 6 is a simplified diagrammatic representation similar to Fig. 2 of a further system of the invention.

Referring to Fig. 1, there is shown an optical system for a simple two-element telescope. The principal components of the system are a thin Mangin mirror 10 and a converging lens 12. The mirror 10 consists of a diverging meniscus lens 14 having a concave surface 16 and a convex surface 18. The convex surface 18 is provided with a reflective coating 20. The thickness of the lens element 14 at its axis is small in comparison to the radius of curvature of either face 16,18. The lens 12 is a simple

bi-convex lens. The system further includes an eyepiece 22, which may be of a modified Ramsden type.

A parallel beam of light from a distant object (not shown in the drawing) is represented in Fig. 1 by the parallel rays 24. The beam is incident on the face 16 of the Mangin mirror 10. The beam passes through the lens 14 to the face 18, where it is reflected by the coating 20. The beam thus passes back through the lens 14, and emerges as a parallel emergent beam, represented in Fig. 1 by the rays 26. It will be noted that the incident beam and the emergent beam are symmetrical with respect to the axis of the Mangin mirror 10. The emergent beam defined by the rays 26 forms a parallel incident beam to the lens 12. The resultant emergent beam from the lens 12 is represented in Fig. 1 by the rays 28. The beam then passes through the eyepiece 22 to an observer.

The Mangin mirror 10 gives rise to overcorrected spherical and chromatic aberrations. The selection of a converging lens system (in this case, the lens 12) having correspondingly undercorrected aberrations will result in a combination in which the aberrations are cancelled. The selection of appropriate components will be familiar to a person skilled in the art. If the lenses 12 and 16 are each formed from the same optical material, the secondary

spectrum of the combination may be reduced by at least an order of magnitude as compared with a normal achromatic lens. The use of a different optical material for each lens can reduce the aberration still further.

In the system shown in Fig. 1, the tilt angle of the Mangin mirror 10 is not critical. For moderate tilt angles, for example 10°, a thin Mangin mirror of zero total power produces no astigmatism. The Mangin mirror produces no coma provided that the incident and emergent beams of the mirror are symmetrical. Lateral colour of the image is compensated by the eyepiece.

Fig. 2 illustrates a system for use in a long focus photographic lens. The system includes a thin tilted Mangin mirror 10 as described hereinbefore with reference to Fig. 1, and corresponding features in Fig. 2 have been designated with like reference numerals. The system of Fig. 2 has a converging lens arrangement consisting of two components, 12A and 12B. The lens 12A is a simple bi-convex lens. The lens 12B is concave. The system also includes a plane mirror 30 and a conventional iris diaphragm, at a position indicated in Fig. 2 by the arrows D. The photographic film is located at the focal plane 40 of the system.

A distant object (not shown) gives rise to a parallel incident beam, shown in Fig. 2 by the rays 32. The incident beam first strikes the plane mirror 30, resulting in a parallel reflected beam designated by the rays 34. This parallel beam is incident on the the Mangin mirror 10, which in turn gives rise to a parallel emergent beam, designated 36 in Fig. 2. The beam then passes through the converging lens arrangement 12,12A and reaches a focus at the focal plane 40.

As with the system of Fig. 1, the thin Mangin mirror of zero total power produces no astigmatism for moderate tilt angles, and no coma whilst the incident and emergent light beams are symmetrical. As before, the Mangin mirror 10 produces overcorrected spherical and chromatic aberrations, which may be cancelled by utilising a converging system having correspondingly undercorrected aberrations. Each of the lens elements 12A,12B and 14 may be formed from the same or from different optical materials. It will be appreciated that the system of Fig. 2 has no central obstruction to prevent the use of the conventional iris diaphragm.

Fig. 3 shows an optical system suitable for use in copying applications. A thin Mangin mirror 10 is combined with two similar converging systems to give 1:1 imaging.

In the system illustrated in Fig. 3, each converging system comprises a single bi-convex lens 50A,50B. The lenses 50A,50B are symmetrically disposed with respect to the axis of the Mangin mirror 10. A point object is located on a plane O at a finite distance from the lens 50A, and produces a diverging incident beam represented by the rays 42. The lens 50A produces a parallel emergent beam represented by the rays 44, which is incident on a Mangin mirror 10 tilted with respect to the optical axis of the lens 50A. The Mangin mirror 10 produces a parallel emergent beam, represented by the rays 46. The incident and emergent beams of the Mangin mirror are symmetrical with respect to its axis. The emergent beam is incident on the second converging lens 50B, which produces a beam represented by the rays 48, coming to a focus on the plane designated I at a finite distance from the lens 50B.

An alternative copying system is shown in Fig. 4. The system includes a thick Mangin mirror 60 in combination with two similar converging systems 70A,70B. In the diagram, each converging system is shown as a single bi-convex lens. A point object is located on a plane O at a finite distance from the lens 70A. Light from the object is incident on the lens and produces a diverging emergent beam represented in Fig. 4 by the rays 66. This beam is incident on the Mangin mirror 60, which

is tilted with respect to the optical axis of the lens 70A. The mirror 60 produces a converging emergent beam represented by the rays 68. The incident and emerging beams of the Mangin mirror are symmetrical with respect to its axis. The emergent beam is incident on the second converging lens 70B, which produces an emergent beam coming into focus on the plane I at a finite distance from the lens 70B.

In each of the copying systems shown in Figures 3 and 4 the Mangin mirror is arranged such that there will be no coma (the incident and emergent beams are symmetrical with respect to the mirror) and no astigmatism (for the thin Mangin mirror, the total power is zero, thus there is no convergence or divergence, and for the thick mirror the power is non zero). It will be appreciated that in the case of the system shown in Fig. 4 aberrations would also be eliminated if the mirror worked with a converging incident and diverging emergent beam.

Fig. 5 shows a simple system similar to that of Fig. 1, but which employs two tilted Mangin mirror components 80, 82. Each Mangin mirror has a mirror coating 20 on its convex surface. In each case, the thickness of the lens is small in comparison to the radius of curvature of either face of the Mangin mirror. The system further

includes a converging lens 84.

It will be appreciated that in optical systems of the kind described, if the tilt angle of the mirror component is small, the incident and emergent beams overlap for a considerable distance from the mirror. There must therefore be a significant separation between the tilted component and the converging component of the system. In order to render the system more compact the tilt angle must be increased to allow the converging system to approach the mirror. However, this necessitates an increased tilt of the image plane, which may not be acceptable. The system of Fig. 5 therefore employs two tilted Mangin mirrors in order to mitigate the problem of image plane tilt. Thus, rays 86 define a parallel incident beam from a distant object (not shown) which first strikes the Mangin mirror 82, from which it is reflected to the second tilted Mangin mirror component 80. An emergent beam represented by rays 88 from the mirror 80 is incident on the converging lens 84 and emerges therefrom to form an image. In a modified two-mirror arrangement, one of the mirrors may be of a type having reversed curvature, thus with the reflecting surface on the concave face.

The systems previously described give excellent correction for longitudinal colour faults. However, such

systems do not directly correct for variation of image scale with wavelength, a fault which arises from the need for an appreciable separation between the chromatically uncorrected tilted Mangin mirror and the remainder of the system. Fig. 6 illustrates an alternative optical system which seeks to overcome this difficulty. The system comprises a tilted Mangin mirror component 90 together with a converging lens system 92. The Mangin mirror 90 is formed from two separate elements 90A, 90B which are cemented together to form the mirror 90, which has a convex surface 94 with a reflective coating 96, and a concave surface 98. The elements 90A, 90B are each formed from a different optical glass, the glasses in this examples being chosen to make the Mangin mirror achromatic whilst having zero total power.

The converging system 92 is also an achromatic system, and is formed from two elements.

A parallel beam of light from a distant object (not shown in the drawing) is represented in Fig. 6 by the parallel rays 100. The beam 100 passes through the components 90A, 90B and is reflected by the coating 96, whereupon it passes back through the component and emerges as a parallel emergent beam represented by the rays 102. Both the incident beam and the emergent beam are

symmetrical with respect to the axis of the Mangin mirror 90. The emergent beam forms a parallel incident beam to the converging lens system 92 which focuses the beam at a focal plane 104 to produce an image.

The achromatic Mangin mirror component 90 has residual secondary spectrum aberrations as previously described. These may be cancelled by choosing the converging achromatic system 92 to have aberrations of the opposite sign. The variation of image scale with wavelength is avoided because the coloured rays are not separated after reflection at the Mangin mirror.

There are thus described optical systems which mitigate or obviate the problems of coma, astigmatism and chromatic aberration without the use of expensive or fragile optical materials. The optical path is free from obstructions, and the tilt angle of the Mangin mirror component is not critical.

It will be appreciated that modifications may be made within the scope of the invention. One or more tilted Mangin mirror components may be utilised without departing from the invention as hereinbefore defined, and a mirror having its mirror surface on the concave side may be used. The Mangin mirror can be formed from two

elements cemented together, and each element may be of a different material. The combination of materials may be selected to give any desired properties to the mirror. The converging system may take any appropriate form. Various optical materials may be used for the converging system and for the lens component of the Mengin mirror. The system can be used for any wavelength for which a transparent material is available.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. An optical system comprising at least one tilted thin Mangin mirror component having zero total power, the or each mirror component being arranged to receive an incident light beam from an object and thereby produce an emergent light beam, the incident and emergent beams being symmetrical with respect to the axis of the mirror component, and a converging lens arrangement, the lens arrangement receiving the emergent beam from the mirror component or components to form an image.

2. An optical system according to claim 1 in which the Mangin mirror component comprises a single element.

3. An optical system according to claim 1 in which the Mangin mirror component comprises two elements cemented together, each element being of a different optical material so that the Mangin mirror is achromatic.

4. An optical system according to any of the preceding claims including a single Mangin mirror having its mirror surface on the convex side thereof.

5. A system according to any of the preceding claims

and adapted to receive a parallel incident light beam.

6. A system according to any of the preceding claims and including an eyepiece.

7. A system according to any of the preceding claims in which the Mangin mirror component and the converging lens arrangement are of different optical materials.

8. A system according to any of the preceding claims including an iris diaphragm.

9. A system according to any of the preceding claims including a plane mirror.

10. An optical system comprising at least one tilted thick Mangin mirror component having non-zero total power, the or each mirror component being arranged to receive an incident light beam from an object and thereby produce an emergent light beam to form an image, the incident and emergent light beams being symmetrical with respect to the axis of the mirror component, and a converging lens arrangement, the lens arrangement receiving the emergent beam from the mirror component or components to form an image.

11. A system according to claim 10 in which the Mangin mirror component comprises a single element.

12. A system according to claim 10 in which the Mangin mirror component comprises two elements cemented together, each element being of a different optical material so that the Mangin mirror is achromatic.

13. An optical system according to any of claims 10 to 12 and including a single Mangin mirror having its mirror surface on the convex side thereof.

14. A telescope including an optical system according to any of the preceding claims.

15. A photographic lens arrangement including an optical system according to any of the preceding claims.

16. A copying system including an optical system according to any of the preceding claims.

17. An optical system substantially as hereinbefore described with reference to the accompanying drawings.

18. Any novel subject matter or combination including novel subject matter disclosed, whether or not within the

scope of or relating to the same invention as any of the preceding claims.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9315214.8

Relevant Technical fields
(i) UK Cl (Edition L) G2J (JB7C11)

(ii) Int Cl (Edition 5) G02B

Databases (see over)
(i) UK Patent Office

(ii)

Search Examiner

MR C J ROSS

Date of Search

7 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1-17

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 0812968 (S.A.A.J.) - see especially Figure 2	1 at least
X	EP 0266005 A2 (PHILIPS) - see especially page 1 line 42 on	1 at least

ms - doc99\fil002199

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).